Market Power in Power Market

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Abstract

In the absence of regulation, exercise of market power by generators can substantially deviate the market clearing price and quantity from a fair and truly competitive outcome. We analyze the role of demand elasticity in calculating the market power of the generators of electricity. We discuss scenarios with different elasticities of demand for electricity and see the impact on market price and quantity. A new index for measuring market power based on elasticity of demand is provided. This study analyzes the issue of market power in California using the day-ahead market data and the *elasticity index*. The data provides evidence of growth in demand, increase in demand elasticity and decrease in supply between June 1998 and 2000. Our results show that consumers can considerably influence the market clearing price if they become more sensitive to price changes.

Key Words: Market power; demand elasticity; market clearing price.

1 Introduction

Since the deregulation of the electricity market, the issue of market power of the generators has come to the forefront. Market power of a generator is defined as the generator's ability to increase the price beyond competitive and fair levels. A generator can offer prices higher than its cost, withhold capacity, manipulate market price to its advantage and earn abnormal profits. In a deregulated market, the lack of competition among generators can result in significant price increase for the consumers. There have been several indices in the literature which measure the market power of the generators. We discuss them in the next section in detail. In this paper, we consider issues related to the market power of the consumers and provide a new index that measures the consumers' ability to influence the price. Both consumers and generators try to exercise their powers to move the price in their favor. A generator can exercise market power in the following ways:

1. **Control over market price**: In the electricity market, some generators can substantially control the market price without having any control over the market share e.g. Reliability Must Run (RMR), critical, constrained-on, bottleneck

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and quick star generators. The generators can also have `spatial market power` which lets them take advantage of their geographic location.

2. **Control over market share**: Generators which possess significant share of the market, have natural monopolistic or oligopolistic power. They can exercise their market power by restricting output and increasing price.

In a market with few consumers, monopsony power can be executed by the consumers provided that the demand for the commodity is elastic. By reducing the demand, consumers can create excess supply and cause a drop in price. However, if the demand is inelastic even a monopsonist cannot execute any power. For a must-have commodity like electricity, the demand is fairly inelastic, allowing suppliers to exploit their consumers. [1] explains how the sequential nature of the California market combined with inelastic demand for electricity does not allow even a monopsonist to exercise market power.

2 Quantitative Indices of Market Power

In this section, we discuss different indices that measure the market power of the generators and consumers. The HHI index discussed in [4] measures the potential to execute market power based on generators' control over the market share. Higher the market share, greater is the possibility of executing market power. The Pivotal Supplier Index (PSI) of [2] measures the frequency of a generator's control over market price given its pivotal status. The next subsections describe the details of the indices. The *Elasticity Index* developed here measures the extent of consumers' control over the market price during periods of excess demand.

2.1 HHI Index

The Herfindahl-Hirschman Index is the sum of the squares of the market shares. In percentage measurement, the index for a monopoly would be 100*100 and 0 for perfect competition (assuming there are infinitely many companies with equal share.) The critical range for HHI is assumed to be between 1800 and 2500. HHI of above 2500 would imply lack of competition in the market. The problem with the HHI index is that it measures only the market concentration as an indicator of market power. If demand is more than supply, every seller can have market power regardless of how small their market share is and how small HHI is. The critical marginal generators, who determine the market clearing price, can exercise market power without owning a big market share. Also, if a generator with a big market share is a net purchaser of electricity, it may not exercise any market power. These factors are not captured in the HHI index.

2.2 Pivotal Supplier Index

In [2], bushnell et al. have provided another measure of market power which looks at the residual demand that must be served by the pivotal supplier. If this residual demand is in excess of other firms' capacity, the pivotal supplier can exercise market power. It is measured in the following way for generator i.

$$PSI_{it} = \begin{cases} 1 & \text{if } D_t - \sum_{j \neq i} GC_j - IC > 0 \\ 0 & \text{if } D_t - \sum_{j \neq i} GC_j - IC \leq 0 \end{cases}$$

where D_t is the aggregate market demand. GC_j is the maximum generating capacity of generator j. IC is the total maximum import capacity. If the residual demand is positive, PSI for period t for generator i is 1 otherwise it is 0. The PSI can be calculated over a time period T by summing up all the number of hours during which its supply is pivotal.

$$PSI_i = \frac{1}{T} \sum_{t=1}^{T} PSI_{it}$$

This gives the percentage of time over period T when the generator's status is pivotal. The higher the PSI, greater the market power of the generator.

The PSI index unlike the HHI index which is a concentration measure, takes into account the level of demand. It can measure the market power of an individual generator based on the demand it faces. However, it does not consider the elasticity of demand. If the PSI is very high and the consumers have high elasticity of demand, the generator may not be able to exercise much market power. But if the demand is inelastic, it can raise the price to almost any level it wants.

2.3 Consumers' Elasticity Index

The HHI and the PSI index described above, are indices which measure suppliers' market power without taking into consideration the characteristics of demand. These indices calculate the market power that suppliers hold over consumers. None of them addresses the issue of flexibility in consumption and the power consumers might have in affecting the market price. Here, we provide the *Elasticity Index* (EI), based on the elasticity of demand, e_d, which calculates the responsiveness of demand to changes in price. Elasticity of demand measures the responsiveness of quantity demanded to changes in price. It gives the percentage change in quantity demanded when price changes by one percent. If q_d is the quantity demanded, p is the price, e_d can be expressed as:

$$e_d = \frac{dq_d}{dp} \frac{p}{q_d}$$

High elasticity of demand of a commodity shows that consumers have higher control over consumption of that commodity. Consumers who can cut down the consumption as soon as the price rises show that they possess the power to stop the exploitation by the generators if excessive price is charged. On the other hand if the demand is inelastic, the generators can increase the price to any unreasonable level and still stay in business.

To calculate the *Elasticity Index*, we first find periods of excess demand for electricity. In periods of excess supply, the generators compete against each other to fulfill the demand. The competition among generators keeps the price and profits at normal levels. However, in the periods of excess demand, suppliers have the potential of executing market power and charging more than the fair price. At that time, the elasticity of demand becomes important since it can change the behavior of the generators and possibly stop their excessive and unfair charges. The *Elasticity Index*, EI, which is based on the demand elasticity, measures the market power of the consumers. To calculate EI, we first identify the periods of excess demand. For each of these periods of $D_t > S_t$, we calculate the elasticity of market demand, and then take the average over all periods to find the elasticity index. D_t is the aggregate demand in period t and S_t is the aggregate supply in period t. t is time measured in hours,[3]

$$EI = \frac{\sum_{t=1}^{n} |(e_d)_t|}{n} \qquad \text{if } D_t > S_t$$

EI not only shows how often a market has excess demand,[4] it also provides a quantitative measure of the consumers' power in terms of e_d. Since EI measures the market power of the consumers, its relationship with the market power of the generators is negative. A higher EI means a market with more elastic demand and hence a lower opportunity for exercising market power by the generators. e_d is likely to be different for different hours. The peak hours usually correspond to low e_d and slack hours to high e_d. Electricity being a commodity with no easy substitutes, the e_d is likely to vary between 0 and 0.5[5]. We apply this index to the California data in Section 3 to observe the demand behavior of the consumers in California and its impact on the market clearing price.

3 Application to Real Data

3.1 Data

We use the day-ahead aggregate supply and demand bid curves data of hourly frequency, for the month of June for years 1998 to 2000 for our analysis. This data is available on *The University of California Energy Institute (UCEI)* site.[6] Hourly demand elasticities are calculated using the hourly demand bid curve data. The day ahead unconstrained hourly market clearing price and quantities are also acquired from the same site.

Figure 1 shows the market supply and demand curves for electricity for a typical hour in June 2000 in California. The shapes of these curves reflect what would be intuitively expected. The demand curve is inelastic at low consumption levels but becomes more elastic and responsive to prices as consumers' subsistence level needs are met. All consumers require a basic amount of electricity for which they are willing to pay almost any price but as their basic needs are taken care of, their superficial demand becomes flexible and responsive to increase in price. On the other hand, opposite is

[3]It could be any other time unit.
[4]The value of n gives the number of periods with excess demand.
[5]See [2] and [7].
[6]http://www.ucei.berkeley.edu/ucei/datamine/datamine.htm

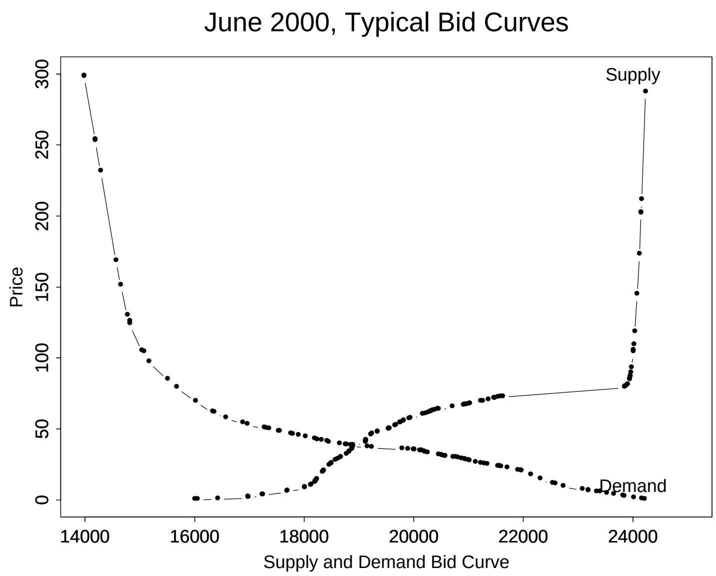

Figure 1: Demand and Supply for Electricity

true for the generators. At low levels of quantity, because of the startup costs and other fixed costs, the supply is elastic. However, once the generator has entered the market and incurred those costs, it is only the variable costs that need to be recovered to keep the plant operational. So at higher levels of quantity, the supply curve becomes more inelastic and less responsive to price. Another reason why the supply becomes more inelastic at higher levels of quantity is that some of the generators may have reached full capacity and cannot increase generation given their plant size.

3.2 Curious California

We pick the month of June for our analysis in California since the prices were exceptionally high in June of 2000 compared to June of 1998 and 1999. Figure 2 shows that between 1998 and 2000, the aggregate demand curve changed in two significant ways; first, the demand curve shifted to the right reflecting a growth in demand; second, the demand elasticity increased substantially implying that in June 2000, the demand became much more responsive to price compared to June 1998. On the contrary, the supply elasticity showed no substantial change over time and the aggregate supply decreased significantly between 1998 and 2000. One possible explanation for drop in supply could be that the generators were executing market power and creating artificial shortage of electricity. Another reason may be that the generators were genuinely withholding capacity to balance the demand and supply given the high prices and elasticity of demand. As gas prices went up along with the elasticity of demand, generators realized that they would not be able to sell as much electricity as they have been in the past and felt compelled to cut back on their supply.

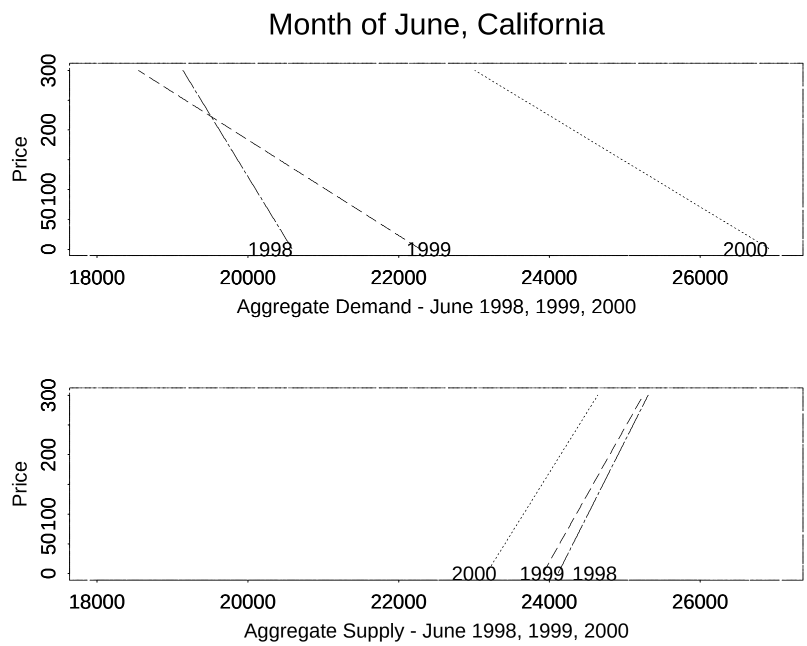

Figure 2: Aggregate Demand and Supply for Electricity in June

Figure 3 shows the relationship between the demand elasticity and the unconstrained market clearing price (UMCP) for different years on an hourly basis. It shows that in California, even though the demand elasticity increased substantially in June 2000, growing demand accompanied with falling supply could not prevent it from resulting in higher prices. Supply had fallen so much short that in the real time market, price often reached close to the price cap level of \$750 in June 2000. This kind of behavior prevented consumers from reaping full benefits of higher demand elasticity in California. Hence high demand elasticity continued to accompany high market clearing prices. June 1999 graph looks interesting with data divided into two clusters of low and high demand elasticities. One with the high e_d corresponds to low UMCP implying that consumers' responsiveness to increase in price, successfully brought down the UMCP. The cluster with low elasticity corresponds to a broad range of UMCP indicating that in periods of low elasticity it is easier for the generators to exploit the consumers and charge a high price. Most of the points with low elasticity and low UMCP in June 1999 correspond to the periods where $D_t < S_t$ and generators have no market power. Given the abundance in supply in June 1998, it is not surprising that prices remained very low and the demand stayed insensitive to changes in price.

Figure 4 attempts to separate the effect of drop in supply and increase in demand elasticity on the market clearing price in June 2000. The aggregate demand and supply curves are derived by fitting a linear curve on the hourly bid data for the month of June. The first graph shows the intersection of the aggregate demand and supply curves for

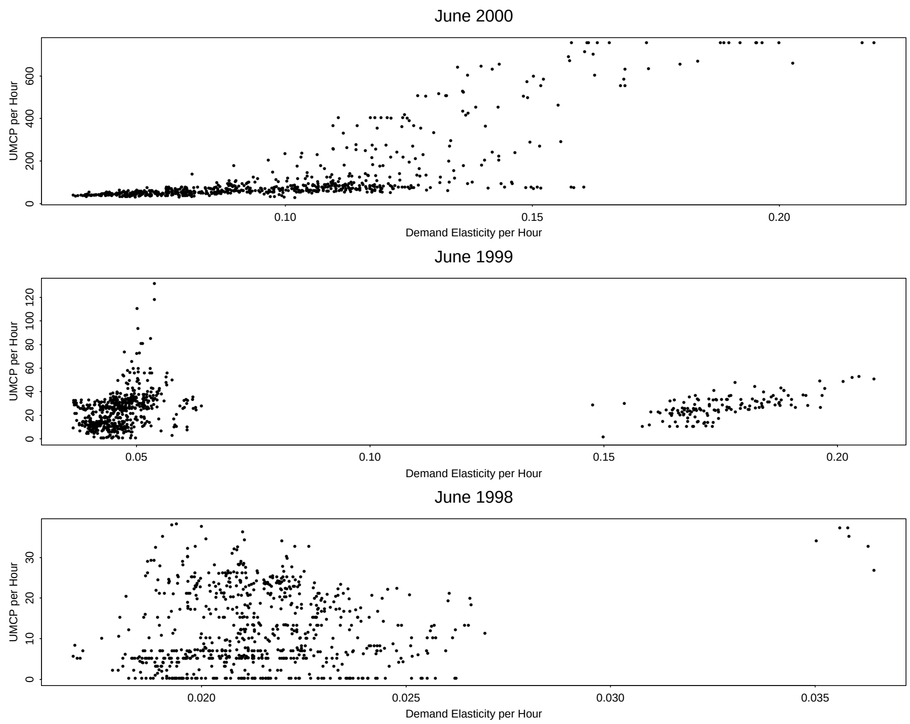

Figure 3: Relationship between the elasticity of demand and the market clearing price for each hour in June of 1998, 1999 and 2000.

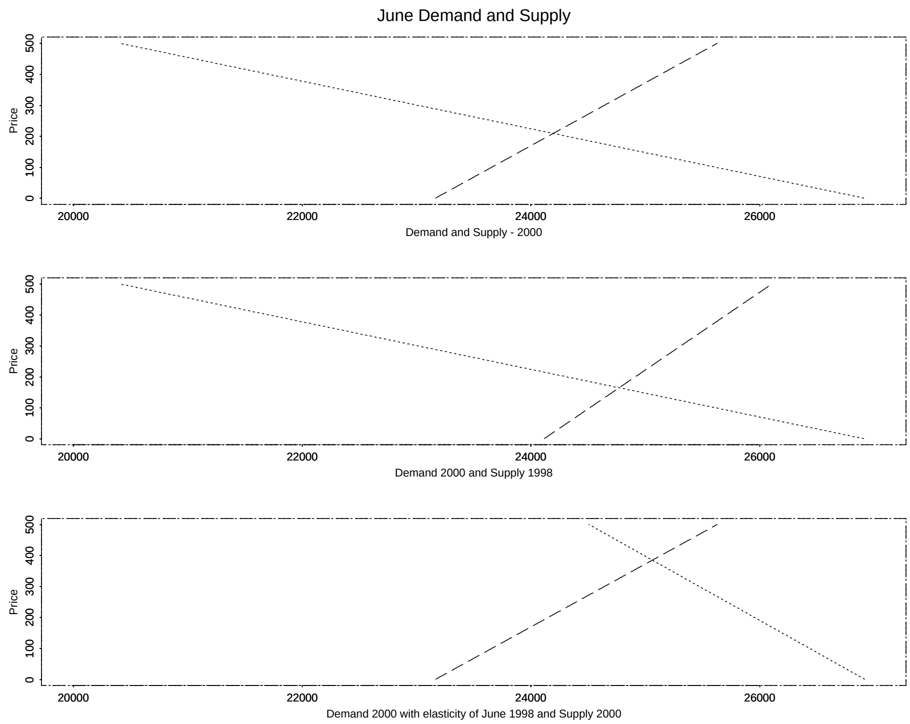

Figure 4: Separating the effect of demand elasticity and decrease in supply on the market clearing price in June 2000.

June 2000 resulting in a MCP of 209\$$/MWh$. The second graph shows that if the aggregate supply had not fallen in June 2000 and was maintained at the level of June 1998, the MCP would have been 165\$$/MWh$. This implies that the shortage in supply caused the price to go up by 44\$$/MWh$ in June 2000. The third graph shows that if the supply of June 2000 had encountered the demand of June 2000 but with a demand elasticity of June 1998, the MCP would have been 385\$$/MWh$. A low elasticity of demand combined with a drop in supply would have resulted in an average market clearing price of 385\$$/MWh$ in June 2000. This shows that higher sensitivity and responsiveness on consumers part alone saved them an average of 176\$$/MWh$.[7] The fact that we find high demand elasticity associated with high UMCP in June 2000, does not mean that demand elasticity has no influence in bringing down MCP. Our analysis shows that in the absence of increase in demand elasticity, the MCP would have been much more. The increased sensitivity of demand to prices helped the consumers from being exploited further by the suppliers serving in a market with excess demand.

Table 1 shows the demand elasticities and unconstrained MCP values for the peak and off-peak periods in June. Peak periods are the periods of excess demand and defined to be the period when the maximum aggregate demand cannot be met with the

[7]This is the difference between 385 and 209.

maximum aggregate supply available.[8] If the total demand cannot be served with the entire available supply at any price, it is called a peak period or hour (since we have hourly data for each demand and supply curve). Any hour that is not peak is defined as off-peak period/hour. Based on this definition, we separated the peak and off-peak hours in June for years 1998-2000. According to this definition, June 1998 had no peak hours. While June of 1999 had 33 peak hours and June of 2000 had 483 peak hours out of a total of 720 hours in June. This shows that there was more opportunity for the generators to execute market power in June 2000 as opposed to June 1998 and 1999. To offset that, the average elasticity of demand went up from 0.05 in 1999 to 0.11 in 2000. In off-peak hours it went up from 0.02 to 0.08 over the three years. Similarly, the UMCP went up in both peak and off-peak hours, though the increase in UMCP in peak hours is significantly higher than the increase in off-peak hours. Given the outrageously high prices during the peak hours in June 2000, it is not surprising that the demand elasticity went up to 0.11.

Table 1

Average Absolute Elasticity of Demand and Unconstrained Market Clearing Price in June[9]

e_d	1998	1999	2000
Peak	NA	0.05	0.11
Off-peak	0.02	0.07	0.08
UMCP	1998	1999	2000
Peak	NA	64.84	157.20
Off-peak	12.09	21.54	44.89

Using the above definition for determining the peak/excess demand periods, we calculate the *elasticity index* for the California data. The results in Table 2 show that EI went up between 1999 and 2000. Consumers became more sensitive and responsive to price changes in June 2000. Our analysis shows that a higher EI may not necessarily lead to lower MCP if the shortage in the market is excessive and suppliers are able to exploit that information.

[8] The results remained qualitatively the same when peak period was defined to be the period when average total supply could not meet the average total demand.

[9] NA implies that there are no peak periods in the June 1998 based on our definition of a peak period.

Table 2

Market Power in June as Measured by the Elasticity Index

Year	1998	1999	2000
EI	0	0.05	0.11

4 Summary and Conclusions

This study analyzes the issue of market power in the electricity market. Using California's day-ahead hourly data for the month of June, it can be shown that California encountered significant growth in demand and drop in supply for electricity between June 1998 and 2000. The average price per megawatt in June 2000 was 209$. If the consumers had not become more responsive to price increase, and demand had stayed as inelastic as it was in 1998, the price per megawatt would have been 385$ in June 2000. This means consumers would have faced another 85% increase in their electricity bills if demand had not become more elastic.

From the above analysis, it is apparent that the lack of response on consumer side can enhance the market power of the generators. Given that electricity is a "must-have" commodity and there is no easy substitute for it, its demand stays fairly inelastic. This is especially true for residential and small commercial consumers. Only the big industrial consumers can afford to have elastic demand. To some extent, consumers may be able to respond to the changes in price of electricity if better communication and time of day pricing facilities could be made available. Increasing demand elasticity can certainly influence the behavior of generators and reduce the market power abuse. Construction of new plants, investment in transmission network, limiting and capping the price of special characteristic generators are some alternative ways to increase the competitiveness of the electricity market and mitigate market power of the generators.

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